Symposium on Energy Efficient Electronic Systems (E3S) **CITRIS / UCB**

What the Real World Tells Us about Saving Energy in Electronics **Bruce Nordman**

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Overview

- · Why care?
- Electronics Energy Use
- Things we know
- Efficiency Opportunities
- Building networks



Networks a principle theme / example

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"What the real world tells us about saving energy in electronics"

- · What are "electronics"
 - "Devices whose primary function is information"
 - Computation, communication, storage, display
- Potential savings derive from actual use
- · What is relevant in the real world besides circuits
 - People, organizations, economics, public sector, ...
- · How to cause future savings

Why care about electronics, energy?

- Core
 - Energy
 - Carbon
 - \$\$€€£¥
- Extreme conditions
 - Power deserts (no mains)
 - Power oceans (datacenters)
 - Power ponds (e.g. notebook)

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First, Think Broadly

















How much energy does The Internet use?



"At least 100 million nodes on the Internet, ... add up to ... 8% of total U.S. demand. ... It's now reasonable to project that half of the electric grid will be powering the digital- Internet economy within the next decade."

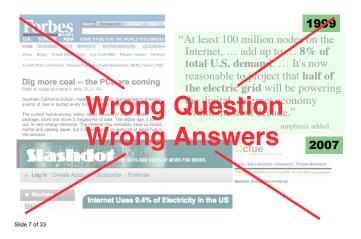






Internet Uses 9.4% of Electricity In the US

How much energy does The Internet use?

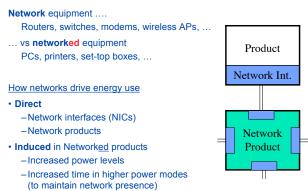


Some questions worth asking

- How much energy does all electronics use? ... network equipment?
- · Where is all this headed?
- How much can we reasonably save in network eqt.?
 ... in edge devices?
- [How much energy does IT avoid]
- What are research and implementation priorities?

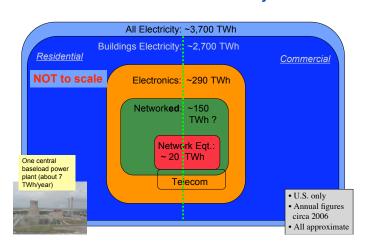
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Networks and Energy

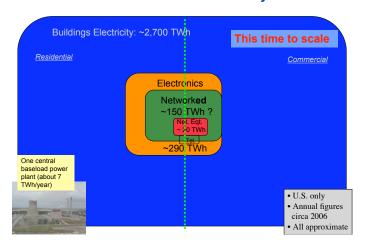


Network induced consumption > all direct
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Electronics / network electricity use



Electronics / network electricity use



What is in that 290 TWh/year?

				-	
Data Centers			Residential		
_	.7	Servers Storage Network	Informat 7.3 2.6 21	tion Technology Modem, router, etc. Imaging PC, Desktop	
10		Telecom	2.8 7.7	PC, Notebook Monitors	
37	.9	TOTAL	6	er Electronics Rech. Electronics	
Co	ommerc	ial	5 4.4	VCR 4 DVD player	
47	2	PC, Desktop	1.6	Security system	
**		PC, Notebook	51	TV, Analog	
11		Monitors	16 2.3	TV, Digital Clock Radio	
9	.7	Copiers	10	STB, cable	
5	.7	Printers	9	STB, satellite	
8	.8	Network	6.1 6.2 2.2	Stereo Compact Audio Home Theater	
89	.8	TOTAL	0.7	Portable Audio	
Slide 12 of 33			161.9	TOTAL	

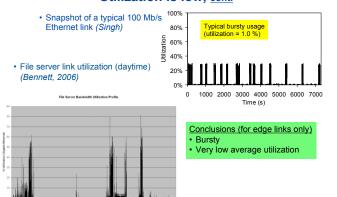
What is in that 290 TWh/year?

Location		Function	
Data Centers	13%	Computing	35%
Commercial	30%	Communication	19%
Residential	57%	Storage	4%
		Display	42%

- These figures rough estimates for 2006
- · None of this includes cooling, UPS, or other infrastructure

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Things we know: Utilization is low, cont.



Things we know: **Utilization** is low

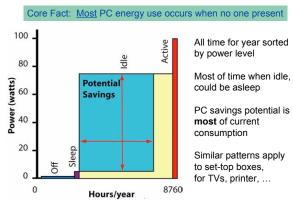
• Data networks are lightly utilized, and will stay that way, A. M. Odlyzko, Review of Network Economics, 2003

Low utilization is norm in life — e.g. cars

- Average U.S. car ~12,000 miles/year = 1.5 miles/hour
- If capacity is 75 mph, this is 2% utilization

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Things we know: Edge device energy is mostly idle

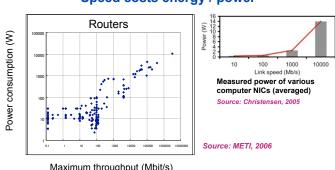


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Things we know: Edge device energy is mostly idle, cont.

- Annual energy consumption above idle level
 - Servers: < 5%
 - Desktop PCs: < 3%
- IP phones: Active consumption < 5% of total
- Set-top boxes: < 50% (probably much less; depends on defn.)
- VCRs < 50% playing or recording

Things we know: Speed costs energy / power



Maximum throughput (Mbit/s)

Energy cost is a function of <u>capacity</u>, not <u>throughput</u>

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Things we know: Economics matter

- Most energy efficiency investments save >> first cost
 "Not a free lunch, but one you get paid to eat"*
- Rampant market failures
 - Split incentives between designers, purchasers
 - ... purchasers, energy cost payers
 - ... payers, users
 - Lack of information
 - Inability to use efficiency information
- · Business-as-usual leads to large energy waste

*paraphrased from Amory Lovins

Things we know: People (users) matter

· Only reason electronics exist

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How should we think about networks and energy?

Approaches / Focus

- Device
 - AC*-powered products
- Lin
 - Capacity, usage, distance, technology
- Throughput
 - Traffic totals, patterns, distribution
- Application / Protocol
 - Drivers of infrastructure, nodes
- Context
 - In-use / not, time-sensitive / not, etc.

Essential to use all approaches simultaneously

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Efficiency Approaches

Product Network Interface Protocol / **Focus Product Focus Application Focus Focus** Examples: Energy Efficient CE **Proxving Energy Star** Need all approaches

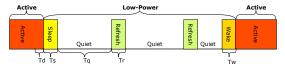
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Finding Energy Savings Opportunities

Sample approaches

- Relax assumptions commonly made about networks
 —when feasible (rarely in core); mine wireless technology
 —these assumptions drive systems to peak performance
 - · average conditions require less energy
 - many assumptions tied to latency
- Design for <u>average</u> condition, not just peak
 —rely on data about typical use
- Use Network to gather info about savings opportunities
- Use Network to enable edge device savings

Energy Efficient Ethernet



- IEEE 802.3az created to standardize EEE
- Standards process began with ALR; eventually settled on alternate method "Low Power Idle"
 - Stop transmitting between packetsSwitch now takes *micro*seconds
- · Standards process needs about 1 more year
 - Goal to get EEE technology into ALL Ethernet network hardware globally over next few years



Energy

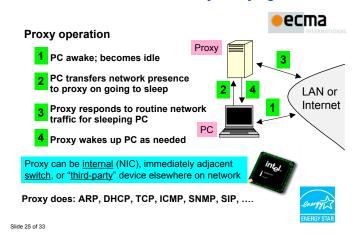
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Ethernet

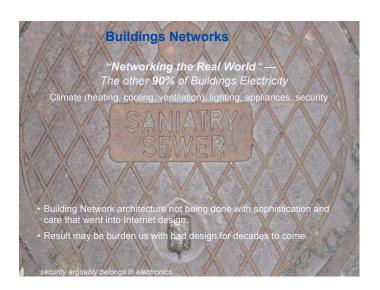


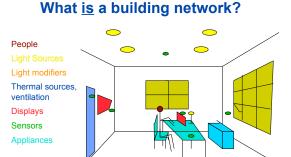
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Network Connectivity Proxying





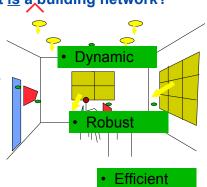




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really good What <u>is</u> a building network?

- PeopleLight Sou
- Light courses
- Light modifiers
- Thermal sources
- Displays
- Sensors
- Appliances



Buildings Networks

- Needs
- Design building networks for next century
- Embrace Internet Protocol and standard network tech.
- · Adopt goal of "Universal Interoperability"
 - Across building types, geography, end uses, people, time, ...
- · Create standard "dictionary" of real world
 - Building elements, ideas, characteristics, actions, ...
- Be prepared to jettison any / all existing technology

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Collective Action

- Common in electronics
 - Grid

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- Technical standards
 - Mechanical, electrical, software
- Essential for savings
 - Public policy
 - Technical standards
 - Industry consortia







• Standards can mandate or prohibit efficiency features

Summary

- Common "wisdom" on electronics and energy may not be valid
- No substitute for empirical data
- Networks increasingly important
- Utilization is low
- Building networks a key priority



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Thank you!

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